Lesson 2:

Temperature, Pressure, and the Earth

Students explore the effects of pressure on temperature and states of matter and use this information to infer the conditions of the interior of the Earth.

Main Lesson Concept: Temperature and pressure are key factors that determine geologic conditions.

Scientific Question: What key factors determine a planet's geologic conditions?

Objectives	Standards
• Students will explain that temperature and pressure are key factors that determine geologic conditions. • Students will explain that the amount of temperature or pressure required to change states differs with substances due to the strength of their molecular bonds.	**Partially meets**: 2061: 4C (6-8) #1 NSES: D (5-8) #1.1

Assessment	Abstract of Lesson
Interior of the Earth drawings and descriptions, and responses to questions in Astro Journal.	Students explore the effects of pressure on solids and explore the effect of pressure on temperature. They conclude that pressure can change the shape of a solid and that increased pressure can increase temperature. Students physically model a solid changing state due to pressure changes. Students draw and describe the interior of the Earth, inferring that the interior of the Earth is hot and the mantle is a flowing solid.

Prerequisite Concepts	Major Concepts

• The following geologic characteristics allow Earth to remain habitable to humans:
  • Liquid outer core (coupled with the planet's rotation and a thick atmosphere)
  • Viscous mantle (slow motion)
  • Slow motion of crust and upper mantle (lithosphere) of 3-5 cm/year (Geology Lesson 1)
• Heating and cooling may cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions. (2061: 4D (3-5) #1)
• Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. (2061: 4D (6-8) #3, Astronomy Lessons 4-6)
	• Pressure affects temperature.
	• The weight of overlying layers causes pressure and temperature to increase as you go deeper into the Earth.
	• Different substances require different amounts of pressure or temperature to change states because of the strengths of their molecular bonds.
	• Pressure and temperature determine the states of the Earth's layers.

Suggested Timeline (45-minute periods):
Day 1: Engage and Explore Part 1 sections
Day 2: Explain Part 1 and Explore Part 2 sections
Day 3: Explain Part 2 and Extend sections
Day 4: Evaluate section (approximately 15 minutes)

Materials and Equipment:
- Class set of Astro Journal Lesson 2
- White paper for student drawings of Earth's interior
- 1 balloon (optional)
- 1 ball of clay
- 1 thin piece of wood or other breakable solid such as a twig or cracker
- 1 sponge (optional)
- 1 piece of polystyrene foam (similar to Styrofoam™) (optional)
- 1 plastic putty (similar to Silly Putty™) (optional)
- Chart paper

Materials for Understanding Pressure Activity (each group will need the following):
- Clay to make 4 balls
- Wax paper
- 3 books
- Marble or bouncy ball
- Scales (optional)

Materials for Temperature and Pressure Activity (teacher demo or each group will need the following):
- Safety goggles
- 2 Celsius non-mercury thermometers (digital or plastic are best)
- 2 clear plastic 20-ounce bottles of carbonated soft drink at room temperature
- 2 two-hole rubber stoppers (the right size to fit the opening of the soft drink bottle)
- 2 labels and a pen for soda bottles (or paper and tape to make 2 labels)

Preparation:
- Duplicate a class set of Astro Journal Lesson 2.
- Gather materials for demonstrations and activities.
- Prepare classroom. (Make sure there's enough room for the Change in Pressure Modeling Activity in the Extend/Apply section.)
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

Differentiation:

Accommodations
For students who may have special needs:
- Have them work with a partner on the Astro Journal writing or report orally to the teacher.

Advanced Extensions
Have students predict what the interiors of other planets and moons in our solar system might be like based on what they know about pressure, temperature, and states of matter. Have them research and report on what the interiors of some of these planets and moons are like and why.

Engage (approximately 15 minutes)

1. **Review Geology Lesson 1.**
   - Question: In the Geology training module, what did you determine to be the geologic conditions required for human survival?
   - *Answer: The following geologic characteristics allow Earth to remain habitable to humans:*
     - *Liquid outer core (coupled with the planet's rotation and a thick atmosphere)*
     - *Viscous mantle (slow motion)*
     - *Slow motion of crust and upper mantle (lithosphere) of 3-5 cm/year*

2. **Review states of matter concepts from Astronomy Lessons 3 through 5.**
   - Question: In Astronomy, what did you learn are the states of matter?
   - *Answer: The three states of matter are solid, liquid, and gas.*

   - Question: What did you learn are the properties of each state of matter?
   - *Answer: Solids have a fixed volume and fixed shape. Liquids have a fixed volume and no fixed shape. Gases have no fixed volume and no fixed shape.*

   - Question: What causes each of these states to be different?
   - *Answer: The amount of energy affects the movement of the molecules and their ability to break their bonds with other molecules. In solids, molecules have less energy and their movement is not enough to break the bonds with other molecules. Liquids have more energy, increasing the movement and beginning to break some of the bonds with other molecules, and in gases, the energy has increased enough that molecules can completely break their bonds with other molecules.*

   - Question: What did you observe causes matter to change its state and how is this accomplished?
   - *Answer: Temperature changes state of matter by increasing or decreasing the motion of the molecules and causing changes in the molecular bonds.*

3. **Review how states of matter are important to life (Astronomy Unit and Atmosphere Unit).**
   - Question: How are states of matter important to life?
   - *Answer: Liquid water and the different gases that make up our atmosphere are important to life on Earth.*

4. **Introduce the purpose of the lesson.**
   - Say: Today, we are going to look at how states of matter are important inside the Earth and how that affects human survival.

   - Question: What do you think the inside of the Earth is like in terms of states of matter? How do you know?
   - *Answer: (Allow students to discuss their ideas about this.)*

5. **Introduce the Scientific Question.**
   - Say: The Scientific Question we will be exploring is:
     - What key factors determine a planet's geologic conditions?

   - Question: What do you think happens to those molecules when we eat food?
   - *Answer: (Allow students to share their ideas on this.)*

Explore

Part 1 - (approximately 35 minutes)

1. **Review pressure from Atmosphere Lesson 7.**
   - Explain that in the Atmosphere Unit we demonstrated air pressure using a balloon.
   - Question: When air is blown into a balloon, why does the balloon expand?
   - *Answer: The molecules of air are moving and pressing against the skin of the balloon.*
   - Explain that pressure is the result of the movement of the molecules pressing against a container of some kind or against some other type of matter.
   - Question: What state of matter are the substances that make up air?
   - *Answer: The substances that make up air are gases.*

2. **Guide students in understanding different types of solids.**
   - Show students a ball of clay.
   - Question: What state of matter is this ball of clay?
   - *Answer: The ball of clay is a solid.*
   - Question: What are the properties of a solid?
   - *Answer: A solid has a fixed volume and shape.*
   - Question: If clay is a solid, why can it change shape?
   - *Answer: (Allow students to discuss their ideas about this.)*
   - Say: There are different types of solids. Some solids break when you try to bend them.
   - Use a thin piece of wood, twig, cracker, or other material to show that some solids break when you try to bend them.
   - Say: Other solids change their shape when you bend them.
   - Use a piece of clay to show that some solids change their shape when you bend them.
   - Question: What are some of the differences between the wood and the clay?
   - *Answer: (Allow students to discuss their ideas about this.)*
   - Question: What effect do you think bending has on the molecules that make up the wood? What effect do you think bending has on the molecules that make up the clay?
   - *Answer: (Allow students to discuss their ideas about this.)*
   - Say: The difference is due to the strength of their molecular bonds. When we bend the wood, the molecules that are bonded together break or separate. When we bend the clay, the molecules that are bonded together only bend or stretch.

Note to Teacher: The reason that the bonds break in wood and that the bonds bend in clay involves more understanding of chemistry than we expect students at this age to have. If you want to discuss this topic with students, the reason is that the clay is made up of long chains of molecules that are not linked tightly to one another. This results in bending. In wood, the chains of molecules are shorter, and stronger bonds hold them together. When you apply a force, it results in breaking.

3. Lead students in the Understanding Pressure Activity Part 1.

- Explain that in Atmosphere Lesson 7 we observed pressure on gases, and in today's lesson we are going to observe pressure on a solid to help us understand what happens inside of the Earth.

- Question: What will happen to a ball of clay if more mass is added to it?

- Have students write a hypothesis/prediction in the Part 1 Hypothesis/Prediction section of their Astro Journals.

Student directions:

1. Give each group seven pieces of wax paper and enough clay to make four balls.
2. Have the students make four clay balls that are the same size as the ball that will be used in the second half of this activity.

Note to Teacher: If possible, have the students measure the mass of each ball using a scale. The students can then add clay or remove clay so the four balls are equal in mass.

3. Ask students to lay each ball on the wax paper on their desk.
4. Have books available that can be stacked on top of the clay.
5. Ask the students to observe one ball of clay and draw their observations in the Part 1 Observations section of their Astro Journals. This ball will be used for comparison throughout the rest of the activity.
6. Have the students put a piece of wax paper and then one book on the second ball of clay.
7. Have students record their observations in their Astro Journals.
8. Have students place a piece of wax paper and then two books on top of the third ball of clay.
9. Have students record their observations in their Astro Journals.
10. Have students place a piece of wax paper and then three books on top of the fourth ball of clay.
11. Have students record their observations in their Astro Journals.
12. Have students answer the question in the Part 1 Results section of their Astro Journals.

4. Have students share their observations with the class.

- Question: As you add more books, what happens to the clay?
- *Answer: It becomes more and more flattened.*

- Question: What is causing the clay to be flattened?
- *Answer: Adding more books adds mass on top of the clay. Because of the force of gravity, as the mass on top increases, the clay is squished by the weight of the books on top of it.*

- Explain that as you increase the mass, the amount of pressure is being increased.

- Explain to students that pressure is the amount of force pushing on an object caused by the molecules surrounding it.

5. Lead students in the Understanding Pressure Activity Part 2.

- Question: What will happen if I replaced the clay ball with a ball that was the same size but made of a different substance?
- *Answer: Accept all responses.*

Opportunity for Open Inquiry: Students can use the question above to develop a student-directed experiment. Have students design and carry out their own experiment to answer the question above. If you choose to do this Open Inquiry, skip down to Explore Part 2 once your students have completed their experiments.

- Give each group a ball that is the same size as the clay but is made out of a different material.

Note to Teacher: A rubber ball or another type of ball made out of material that will bend is a good idea so that the books do not roll off the ball. If you do not have enough balls for each group to have one, you could complete the activity above as a demonstration.

- Question: What will happen to this ball if more mass is added to it?

- Have students write a hypothesis/prediction in the Part 2 Hypothesis/Prediction section of their Astro Journals.

Student directions:

1. Have the students place one book on top of the ball.
2. Have students record their observations in the Part 2 Observations section of their Astro Journals.
3. Have students place two books on top of the ball.
4. Have students record their observations in their Astro Journals.
5. Have students place three books on top of the ball.
6. Have students record their observations in their Astro Journals.
7. Have students answer the questions in the Part 2 Results and Conclusions sections in their Astro Journals.

Explain — Part 1 - (approximately 15 minutes)

1. Discuss student results and conclusions from the activity.

- Question: What observations did you make during this activity?
- *Answer: (Allow students to share their observations. In the first part of the activity, students should have observed that adding more mass caused the clay to become more flattened. In the second part of the activity, observations will depend on the type of ball used. Students probably saw that the ball was not as affected by the mass as the clay was.)*

- Question: What would it take to flatten the ball in the second part of the activity? Why?
- *Answer: Most likely the material of the ball in the second part was more firm than the clay. This would result in the ball not being as affected or as flattened by the increase in mass. Much more pressure must be applied to flatten the ball in the second part of the activity.*

- Question: What was the difference between the first part of this activity and the second part of this activity?
- *Answer: The difference between the two parts was the material the balls were made of.*

- Question: By adding more books, what were we increasing in this activity?
- *Answer: By adding more books, we were increasing the mass on the balls.*

- Question: As you increase the mass, what is also being increased?
- *Answer: The amount of pressure is being increased as you increase the mass.*

- Question: What do you think would happen if we repeated this activity with different objects such as a sponge?
- *Answer: (Allow students to share their ideas. Students will most likely respond that the sponge will become flatter under increased pressure from the books.)*

- Question: Imagine that you had a sponge and a piece of polystyrene foam (similar to Styrofoam™) the same size as the sponge. What would happen if we applied the same amount of pressure to both objects?
- *Answer: (Allow students to share their ideas. Students will most likely respond that both objects will flatten. They may also respond that the sponge will flatten more than the polystyrene foam.)*

  Note to Teacher: If you have a sponge and piece of polystyrene foam available, it would be helpful for students to actually observe the activity described above. The sponge will flatten more readily if it is slightly damp.

- Question: Do you think any solid can change shape under pressure?
- *Answer: (Allow students to share their ideas. Students may respond that any solid can change shape under the right amount of pressure.)*

- Say: Any solid can change shape given enough pressure.

- Question: What conclusion can you draw from this activity?
- *Answer: Different substances require different amounts of pressure to change form.*

- Question: Why do you think that different substances require different amounts of pressure to change form?
- *Answer: (Allow students to share their ideas. Students may respond that different substances require different amounts of pressure due to the material that they are made of.)*

- Say: Remember at the beginning of this lesson we learned that the difference between wood breaking and clay bending was due to the strength of their molecular bonds.

- Question: How does this knowledge us help us understand why different substances require different amounts of pressure to change form?
- *Answer: Students should understand that different substances require different amounts of pressure to change form due to the strength of their molecular bonds.*

Explore

Part 2 - (approximately 30 minutes)

1. Guide students in the Temperature and Pressure Activity.

MISCONCEPTION: Heat is the kinetic energy (or movement) of all molecules in a system. Temperature is the measure of the average kinetic energy (or movement) of the molecules of a system. People tend to think of temperature in terms of "hot" and "cold." The problem with this is that "hot" and "cold" need some reference points in order to have value. The temperature of 101 degrees Fahrenheit (F) may be a "hot" day (to some people), but it would be too "cold" to do most kinds of baking or cooking in an oven. What we as people experience as "hot" and "cold" are actually experiences of heat transfer. Heat tends to transfer from where there is a higher temperature to where there is a lower temperature. On that same 101°F day, the temperature of the air around us is higher than our own temperature (98.6°F) so we experience warmth and call the day "hot."

Questions that can bring out this misconception are: What is hot? What is temperature? What does it mean to be hot? How could you explain the heat in terms of motion of molecules?

- Question: What will happen to the temperature of a substance as the pressure increases?
- Have students record their predictions in the Hypothesis/Prediction section of their Astro Journals.
- Explain to students that they will be shaking a half-full carbonated drink to increase the pressure within the bottle. This increases the pressure inside the bottle because it causes lots of little carbon dioxide bubbles to form. Once the small bubbles form, it is easier for larger carbon dioxide bubbles to form. The pressure increases as the bubbles start to "fight" with the liquid for space in the bottle.
- Have students conduct the Temperature and Pressure Activity.

Note To Teacher: Be sure to wear safety goggles and use non-mercury thermometers during this activity. A two-hole stopper is necessary for this activity because too much pressure in the bottle can result in the thermometer being pushed out suddenly. Depending on availability of resources and age of students, this activity can be done as a demonstration or in small groups.

Materials:

- Safety goggles
- 2 Celsius non-mercury thermometers (digital or plastic are best)
- 2 clear plastic 20-ounce bottles of carbonated soft drink at room temperature
- 2 two-hole rubber stoppers (the right size to fit the opening of the soft drink bottle)
- 2 labels and a pen for soda bottles (or paper and tape to make 2 labels)

Procedure:

1. Write down the room temperature in your Astro Journal.
2. Label one bottle "Constant Pressure," and label the second bottle "Increased Pressure."
3. Gently open the "Constant Pressure" soda bottle being sure to lose as little of the carbonation in the liquid as possible. Insert the Celsius thermometer into the carbonated drink to determine if the soda is at room temperature. It is important for this lesson that the soda is at room temperature before the experiment begins.
4. Remove the thermometer and repeat the above step for the "Increased Pressure" soda bottle.
5. Carefully insert one thermometer into one hole of a two-hole stopper. Push the thermometer until it extends 5 to 7 cm below the stopper bottom.
6. Repeat the previous step with the second stopper and thermometer.
7. Slowly pour out half the beverage in each container trying not to lose any of the carbonation.
8. Carefully insert one rubber stopper (with the thermometer) into the top of each soda bottle. Make sure that the stopper is firmly in place and that the thermometer tip is not touching the liquid inside the bottle.
9. Observe and record the temperature of the thermometer for each bottle in the Temperature and Pressure Data Chart in your Astro Journal.
10. Cover the second hole of the rubber stopper of the "Increased Pressure" bottle with one finger. Pick up the bottle of soda and vigorously shake it twice only. Set the bottle on a flat surface.
11. Observe and record the temperature of the "Constant Pressure" and the "Increased Pressure" bottle in your Astro Journal.
12. Pick up the "Increased Pressure" bottle again and shake it two more times. Be sure to keep your finger firmly over the second hole. Set the bottle on a flat surface.
13. Observe and record the temperature of the thermometer of both bottles in your Astro Journal.
14. Continue to shake the "Increased Pressure" bottle twice and observe and record temperature until no further increase is observed. Be sure to record the temperature for both bottles each time.
15. Graph both sets of data using a different colored pen or pencil for each set of data.
16. Respond to the Temperature and Pressure Activity Questions in your Astro Journal.

Note to Teacher: The graphing units are not provided so that students can go through the process of thinking about how best to graph their results. Suggested units are to use pressure (# of shakes) for the x-axis, and temperature in degrees Celsius for the y-axis. Help students to decide on these units by asking such questions as, "What kind of graph will show us a change as the number of shakes increases?" "What units will we want to use across the bottom to see this change?" "What units should we use along the side to help us see what is changing as the number of shakes increases?"

Explain

Part 2 - (approximately 15 minutes)

1. Discuss with students their conclusions from the Temperature and Pressure Activity.

- Question: What was the difference between the graph of the soda bottle that had been shaken and the soda bottle that had not been shaken?
- *Answer: The graph of the soda bottle that had been shaken showed an increase in temperature, and the graph of the soda bottle that had not been shaken remained at a fairly constant temperature.*

- Question: Why do you think this happened?
- *Answer: This happened because we shook one bottle, but we did not shake the other bottle.*

- Question: What did shaking the bottle do to the contents inside the bottle?
- *Answer: Shaking the bottle caused the pressure inside the bottle to increase.*

- Question: What happened to the temperature as the pressure increased?
- *Answer: As the pressure increased, the temperature increased.*

- Question: Earlier in this lesson, you completed an activity with balls of clay. What effect did placing books on top of the balls of clay have?
- *Answer: Adding more books added mass to the clay. This increased mass resulted in increased pressure. The clay changed shape due to the increased pressure from the books.*

- Question: Knowing that pressure affects the shape of solids and the temperature of substances, what might the interior of the Earth be like? Why?
- *Answer: (Allow students to discuss their ideas about this.)*

- Question: In the Geology Training Module, you learned about the interior of the Earth. What is the innermost layer of the Earth?
- *Answer: The innermost layer of the Earth is the core.*

- Question: What layers are on top of the core?
- *Answer: The layers on top of the core are the mantle and the crust.*

- Question: What effect do you think these layers have on the core?
- *Answer: (Allow students to discuss their ideas about this.)*

- Question: What connection can you make between the balls of clay activity and the interior of the Earth?
- *Answer: The layers of the Earth are like the books in the balls of clay activity. The layers push down on each other causing more weight on the layers that are further down. The weight of the overlying layers results in high pressure at the interior of the Earth.*

- Question: Which layer of the Earth do you think is at the most pressure? Why?
- *Answer: The core is at the most pressure due to the weight of the overlying layers.*

- Question: What do you think happens to the temperature as we travel towards the center of the Earth?
- *Answer: The temperature increases as you travel towards the center. One of the reasons is the pressure from the overlying layers.*

Note to Teacher: There are a few reasons why Earth's internal temperature is hot. One of these reasons is pressure from the overlying layers. In other words, the energy from the compaction of the Earth due to gravity is converted to heat energy. Other reasons include energy from the accretion of material when the Earth formed and the decay of radioactive materials inside the Earth. The compaction of Earth due to gravity and the energy from the accretion of the Earth are considered "leftover heating" from Earth's formation, while radioactive decay is a constant (although diminishing) source of heat.

- Question: Which layer of the Earth do you think is the hottest? Why?
- *Answer: The core is the hottest because it is under the most pressure.*

- Say: Earlier in this lesson we learned that some solids, like a thin piece of wood, will break when bent, while some solids like clay can be bent without breaking. There are other solids that can flow. An example of one of these solids is plastic putty (similar to Silly Putty™).

- Discuss students' previous experiences with plastic putty.

- Question: What would happen if you rolled plastic putty into a ball and placed it on a desk?
- *Answer: If you rolled plastic putty into a ball and placed it on a desk, over time it would flow from a ball shape into a flat shape.*

- Question: Which layer of the Earth would be similar to plastic putty? Why?
- *Answer: The Earth's mantle is similar to plastic putty because it is solid, but it flows very slowly.*

- Say: To describe how something flows, scientists use the term viscosity. The slower something flows, the more viscous it is. For example, honey is more viscous than water.

- Question: Do you think scientists would describe the mantle as being more or less viscous than plastic putty? Why?
- *Answer: Scientists would describe the mantle as being more viscous than plastic putty because it flows much more slowly.*

- Write the following chart on the board:

Substance	Viscosity
Air	0.00001 (10^{-5})
Water	0.001 (10^{-3})
Honey	10 (10^{1})
Mantle	100,000,000,000,000,000,000 (10^{20})

- Question: Look at the chart on the board. Which substance listed on the chart moves the slowest? How did you know?
- *Answer: The mantle is the substance that moves the slowest because it has the highest viscosity, 10^{20} (or a 1 with 20 zeros after it).*

- Question: Look at the chart on the board. Which substance listed on the chart moves the fastest? How did you know?
- *Answer: Air is the substance that moves the fastest because it has the lowest viscosity, 10^{-5} (or 0.00001).*

Note to Teacher: For older students, this could lead to a discussion and demonstration on how scientific notation works. For younger students, just write the numbers in standard form.

Extend/Apply (approximately 30 minutes)

1. **Review with students the Matter and Molecules Modeling Activity from Astronomy Lesson 4.**
   - Question: What are the differences between the movement of molecules in solids, liquids, and gases?
   - *Answer: The molecules in solids only vibrate. In liquids, the molecules slide past each other. In gases, the molecules spread out freely.*
   - Have students act as "molecules" in each of the three states of matter.

     Note to Teacher: In a solid, students should be standing somewhat close together with their hands or wrists linked. They should be vibrating, but not moving around. In a liquid, students should now be moving around, but still touching as they pass each other. In a gas, the students should be moving freely. They should be moving around a little more quickly than when they were liquid, and they should be spread out, rarely encountering each other.

2. **Lead students in Change in Pressure Modeling Activity.**
   - Have students begin as a solid.
   - Say: We are increasing the pressure on this solid by adding more mass to the area surrounding it.
   - Question: What' s happening to the temperature of the matter?
   - *Answer: The temperature is increasing.*
   - Have the students model this increase in temperature.

     Note to Teacher: Students should start loosening their connections and moving past each other while continuing to keep contact.
   - Question: What state of matter are you modeling?
   - *Answer: We are modeling a liquid.*
   - Say: We continue to increase the pressure (by adding more mass to it.)
   - Have the students model this increase.

     Note to Teacher: Students should be moving more quickly and independently.
   - Question: What state of matter are you modeling?
   - *Answer: We are modeling a gas.*
   - Raise and lower the "pressure" and have the students adjust their physical model.
   - Say: In the following activity, you will apply what you know about the effects of temperature and pressure to the interior of the Earth.

3. **Have students complete the Conditions of Earth's Interior Activity.**
   - Say: In this activity, you will draw and describe the interior of the Earth using pressure, temperature, and states of matter.

Evaluate (approximately 15 minutes)

1. **Have students share and discuss their drawings and descriptions from the Conditions of Earth's Interior Activity.**
   - Have students explain how their drawings and descriptions illustrate the effect of temperature and pressure on the conditions of Earth's interior.

2. **Discuss students' responses in their Astro Journals to ensure they have mastered the major concepts.**
   - Question: What did you observe is the effect of pressure on matter?
   - *Answer: An increase in pressure causes a change in the state of matter.*

   - Question: How is this change accomplished?
   - *Answer: An increase in pressure causes an increase in temperature that changes states of matter by increasing or decreasing the motion of the molecules and causing changes in molecular bonds.*

   - Question: How do temperature and pressure affect the conditions of Earth's interior?
   - *Answer: The core of the Earth has the most pressure due to the weight of the overlying layers. The core of the Earth is also the hottest because it is under the most pressure.*

3. **Collect students' Astro Journals and evaluate them to ensure they have each mastered the major concepts.**
   - Pressure affects temperature.
   - The weight of overlying layers causes pressure and temperature to increase as you go deeper into the Earth.
   - Different substances require different amounts of pressure or temperature to change states because of the strengths of their molecular bonds.
   - Pressure and temperature determine the states of the Earth's layers.

4. **Bridge to next lesson.**
   - Say: Today we learned that temperature and pressure are key factors that determine geologic conditions. In the next lesson we will learn how the density of materials determines the composition of Earth's layers.

   Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Name:

Class/Period:

Date:

Understanding Pressure Activity Part 1

Scientific Question:

What key factors determine a planet's geologic conditions?

1. Hypothesis/Prediction: What will happen to a ball of clay if more mass is added to it?

Procedure:

1. Make four balls out of clay that are the same size as the ball that will be used in the second half of this activity. Lay these balls on a piece of wax paper.
2. Observe one ball of clay and draw your observations in the row marked "No books" of the Observations chart.
3. Place a piece of wax paper and then one book on the second ball of clay.
4. Record your observations in the row marked "One book."
5. Place a piece of wax paper and then two books on the third ball of clay.
6. Record your observations in the row marked "Two books."
7. Place a piece of wax paper and then three books on the fourth ball of clay.
8. Record your observations in the row marked "Three books."
9. Answer the Results question.

2. Observations: Record your drawings of the clay balls in the chart below.

Number of Books	Drawing of Clay Ball
No books	
One book	
Two books	
Three books	

3. Results: What happened to the clay as more mass was added? Why?

Class/Period:

Name:

Date:

Understanding Pressure Activity Part 2

Procedure:

1. Look at the ball you will be using in Part 2. What will happen to the ball if more mass is added to it? Write a hypothesis/prediction in the space provided below.
2. Observe the ball and draw your observations in the row marked "No books."
3. Place one book on top of the ball.
4. Record your observations in the row marked "One book."
5. Place two books on top of the ball.
6. Record your observations in the row marked "Two books."
7. Place three books on top of the ball.
8. Record your observations in the row marked "Three books."
9. Answer the Part 2 Results and Conclusions questions.

1. Hypothesis/Prediction: What will happen to the ball if more mass is added to it?

2. Observations: Record your drawings of the balls in the chart below.

Number of Books	Drawing of Ball for Part 2
No books	
One book	
Two books	
Three books	

3. Part 2 Results: What happened to the ball in Part 2 as more mass was added? Why?

What would it take to flatten the ball in Part 2? Why?

Name:

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Date:

Understanding Pressure Activity Part 2

4. Conclusions: When mass was added, what was the difference between the clay ball and the ball in Part 2?

What can we conclude about the effects of pressure on different substances? Why do you think this is? (Explain using molecules and bonds.)

Name:

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Understanding Pressure Activity Part 2

1. Prediction: What will happen to the temperature as the pressure increases?

Procedure

1. Write down the room temperature on the next page of your Astro Journal.
2. Label one bottle "Constant Pressure," and label the second bottle "Increased Pressure."
3. Gently open the "Constant Pressure" soda bottle being sure to lose as little of the carbonation in the liquid as possible. Insert the Celsius thermometer into the carbonated drink to determine if the soda is at room temperature. It is important that the soda is at room temperature before the experiment begins.
4. Remove the thermometer and repeat the above step for the "Increased Pressure" soda bottle.
5. Carefully insert one thermometer into one hole of a two-hole stopper. Push the thermometer until it extends 5 to 7 cm below the stopper bottom.
6. Repeat the previous step with the second stopper and thermometer.
7. Slowly pour out half the beverage in each container trying not to lose any of the carbonation.
8. Carefully insert one rubber stopper (with the thermometer) into the top of each soda bottle. Make sure that the stopper is firmly in place and that the thermometer tip is not touching the liquid inside the bottle.
9. Observe and record the temperature of the thermometer for each bottle in your Astro Journal.
10. Cover the second hole of the rubber stopper of the "Increased Pressure" bottle with one finger. Pick up the bottle of soda and vigorously shake it twice only. Set the bottle on a flat surface.
11. Observe and record the temperature of the "Constant Pressure" and the "Increased Pressure" bottle in the Temperature and Data Chart on the next page.
12. Pick up the "Increased Pressure" bottle again and shake it two more times. Be sure to keep your finger firmly over the second hole. Set the bottle on a flat surface.
13. Observe and record the temperature of the thermometer of both bottles in your Astro Journal.
14. Continue to shake the "Increased Pressure" bottle twice and observe and record temperature until no further increase is observed. Be sure to record the temperature for both bottles each time.
15. Graph both sets of data using a different colored pen or pencil for each set of data.
16. Respond to the Temperature and Pressure Activity questions in your Astro Journal.

Name:

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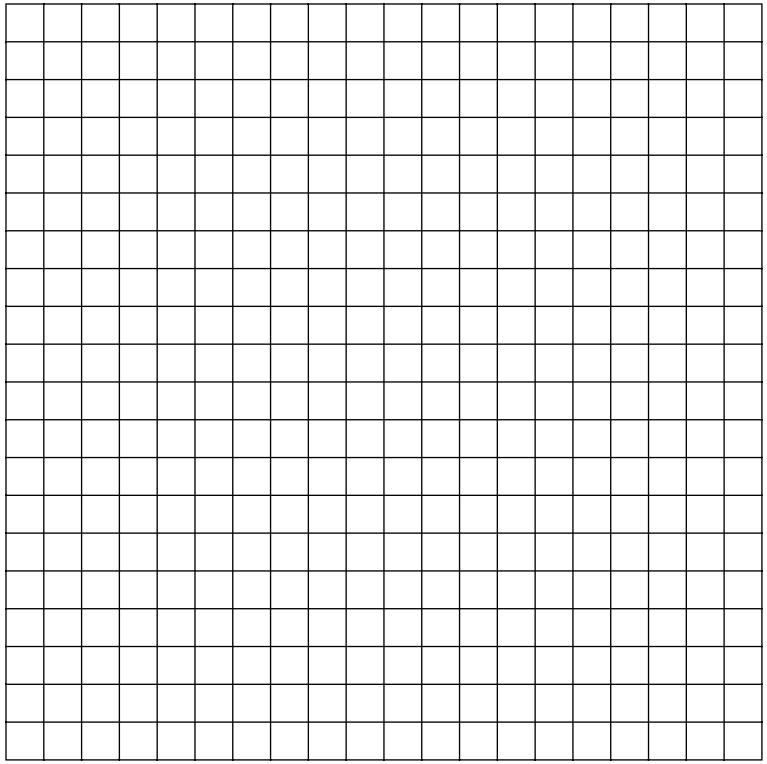
Understanding Pressure Activity Part 2

2. Room temperature: _____

3. Temperature and Pressure Data Chart

Pressure (# of shakes)	Temperature of Constant Pressure Soda Bottle	Temperature of Increased Pressure Soda Bottle
0		
2		
4		
6		
8		
10		

4. Graph both sets of data below. Be sure to use a different color pen or pencil for each set of data.



Name:

Class/Period:

Date:

5. Conclusions: What is the difference between the two graphed lines? Why?

What do the graphs tell us about the relationship between pressure and temperature?

Conditions of Earth's Interior Activity

Draw and describe the interior of the Earth using pressure, temperature, and states of matter. Be sure to explain how pressure and temperature affect the interior of the Earth.

Your drawing and description will be evaluated using the following rubric:

4	• Drawing and description clearly and accurately explain the interior of the Earth using pressure, temperature, and states of matter. • Drawing and description has all required parts and uses excellent reasoning to create an exceptionally powerful and detailed explanation.
3	• Drawing and description clearly and accurately explain the interior of the Earth using pressure, temperature, and states of matter. • Drawing and description has all required parts and uses good reasoning in explanations.
2	• Drawing and description are not completely clear or accurate in explaining the interior of the Earth using pressure, temperature, and states of matter. • Drawing and description has most required parts and uses some good reasoning in explanations.
1	• Drawing and description is not clear or accurate in explaining the interior of the Earth using pressure, temperature, and states of matter, is missing several parts, and uses little or no good reasoning.